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Water budget, crop water productivity and economic return of land and water units for Egyptian crops

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Abstract: Water is an important element of development and evolution. Egypt suffers from limited water resources because it is located within the arid and semi-arid zone. Agriculture is considered the largest consumer of water resources in Egypt. Update the data of water budget for agriculture at intervals is important to identify the total water budget for agricultural crops especially when adding new agricultural areas or using short duration varieties or spread modern irrigation systems in larger areas.

Current research aims to calculate the water budget (WB) for Egyptian crops in the 2016/2017 winter crops and the 2017 season for summer, Nili and perennial crops. CropWat8.0 model was used to calculate the irrigation water requirements for the crops under study. In addition, crop water productivity as well as the economic return of land and water units were calculated.

Results indicated that total cropped area was 6.7 million hectare and its water budget was 62.7 billion m^3.The water budget of Egyptian crops represents 78.4% of the total water resources in Egypt. The highest crop water productivity (CWP) registered for carrot, sugar beet, tomato, onion for winter crops; potato, cantaloupe, watermelon for summer crops. The CWP values for the previous crops exceeded 9 and 5 kg/m^3 for winter and summer crops, respectively. Regarding Nili and perennial crops, the highest ones was found for tomato (5.05 kg/m^3) and sugarcane (4.77 kg/m^3). The highest economic return for the land and water units were recorded for strawberry, peas (dry) and carrot. The economic return per land unit for the three respective crops were 157810, 86467 and 62429 LE/ha, while the economic return per irrigation water requirement (IWR) unit were 18.51, 14.25, 14.00 LE/m^3_{IWR} in the old lands; and 24.69, 19.00 and 18.66 LE/ m^3_{IWR} in the new lands.

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Keywords: water budget; crop water productivity, economics of the land and water units

1. Introduction

Water is an important element of development and evolution. Egypt suffers from limited water resources because they are located within the arid and semi-arid zone. The water resources sector in Egypt meets many challenges such as population growth, climate change and others that affect the self-sufficient from the main food crops and causing increased the gap between production and consumption. All this requires concerted efforts to make good use of this important resource and search for new resources can cover part of the increasing demand for water.

Water and agriculture are strongly interconnected. To grow food, you need water; but the agriculture sector remains highly susceptible to water-related disasters like floods, droughts and typhoons. In turn, water resources are also impacted by agricultural activities, as the largest water-consuming sector globally and a significant source of pollution. So producing food sustainably will require good water management in agriculture, and managing water sustainably will require taking into account the role of agriculture (Guillaume, 2019).

The 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs), and the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) provide both the framework and the targets that should guide global efforts towards more inclusive growth and sustainable livelihoods. Agriculture, through its links to food security, nutrition and health, rural development and growth, and the environment, is a major driver in the attainment of these targets. In the current environment of changing global agricultural markets, agriculture faces a triple challenge. First, it has to increase the production of safe and nutritious food to meet a growing demand driven by population increase. Second, agriculture has to generate jobs and incomes and contribute to poverty eradication and rural economic growth. Finally, agriculture has a major role to play in the sustainable management of natural resources and the adaptation to, and mitigation of climate change which is already affecting the livelihoods of many people, especially the most vulnerable (FAO, 2017). ET based irrigation scheduling is getting wider applications as a means to improve water productivity due to rising concern on water conservation. The environmental demand for water regulates the water requirement of the crops. The process is controlled by other factors like amount of ground coverage by the crops and its geometry, growth stage of the plant, nature and characteristics of the ground surface etc., apart from the meteorological parameters. The concept of reference ET gained importance in agricultural water requirement estimation. (Anjitha Krishna, 2019).

Owing to the difficulty of obtaining accurate field measurements, ET is commonly computed from weather data. A large number of empirical or semi-empirical equations have been developed for assessing crop or reference crop evapotranspiration from meteorological data. Some of the methods are only valid under specific climatic and agronomic conditions and cannot be applied under conditions different from those under which they were originally developed (FAO, No. 56).According to FAO report (Part A - Reference evapotranspiration, ET_o), ET_o can be computed from meteorological data. As a result of an Expert Consultation held in May 1990, the FAO Penman-Monteith method is now recommended as the sole standard method for the definition and computation of the reference evapotranspiration. The FAO Penman-Monteith method requires radiation, air temperature, air humidity and wind speed data.

Little studies on the water budget for Egyptian crops were carried out since the 1970s,

El-Gibali and Badawi (1978) found that total water requirements reached 44.0 B. m^3/ year for whole cropped area considering an irrigation efficiency of 60 %. Ainer et. al. (1999) indicated that the total irrigation requirements were 52.0, 43.9 and 39.0 B.m^3/ year under surface, sprinkler and drip irrigation systems, respectively. Eid et al. (1999) found that the crop water need values of the new lands reached about 5686, 4521 and 3711 million m^3/ year under surface, sprinkler and drip irrigation systems, respectively.

Regarding the total water resources in Egypt, Central Agency for Public Mobilization and Statistics issued a statement which indicated that, Egypt's total water resources in 2016/2017 reached 80.0 billion m^3. This amount comes from 55.5 billion m^3 of Nile River share & 24.5 billion m^3 of agriculture drainage recycling, sewage recycling, rain and flash floods, and desalination. (https://www.elwatannews.com, https://m.akhbarelyom.com/news, http://www.dotmsr.com/news,http://gate.ahram.org.eg/News/2133112.aspx,http://www.fedcoc.org.eg/Default.aspx,). On the other hand, with regard to water efficiency and crop water productivity, FAO (2015) explained that, Water efficiency (WE) is defined as the proportion of water consumed through plant transpiration (and so contributing to plant growth) over the total water applied. It is a dimensionless ratio, often expressed in percentage.

Crop water productivity (CWP)is defined as the production per unit of water transpired or 'crop per drop'. The simplest measure is kg/m^3 transpired (*physical CWP*), but another meaningful measure is net income per unit of water transpired (USD/m^3 or *economic CWP*). Molden et. al. (2007) defined water productivity as the ratio of the net benefits from crop, forestry, fishery, livestock, and mixed agricultural systems to the amount of water required to produce those benefits. They added that, there are important reasons to improve agricultural water productivity:

- To meet the rising demand for food from a growing, wealthier, and increasingly urbanized population, in light of water scarcity.
- To respond to pressures to reallocate water from agriculture to cities and to ensure that water is available for environmental uses.
- To contribute to poverty reduction and economic growth. For the rural poor more productive use of water can mean better nutrition for families, more income, productive employment, and greater equity. Targeting high water productivity can reduce investment costs by reducing the amount of water that has to be withdrawn.

Perry et. al. (2009) indicated that to better understand how different crops, different agroclimatic environments, and different management practices may influence the relationship between crop production and water consumption, we define the water productivity of a crop (WP) as the ratio between the amount of crop produced and the amount of water consumed to obtain such production. Moreover, in defining water productivity, we need to be specific in indicating which product (biomass or yield) and which consumption (transpiration or evapotranspiration) we are referring to. Thus, we can express the water productivity of a crop (WP) as:

- Biomass WP(T) = (kg of biomass)/(m^3 of water transpired).
- Biomass WP(ET) = (kg of biomass)/(m^3 of water evapo-transpired).
- Yield WP(T) = (kg of usable yield)/(m^3 of water transpired).
- Yield WP(ET) = (kg of usable yield)/(m^3 of water evapo-transpired).

The aim of the present study is to find out the total water budget for Egyptian crops, and the percentages of water budget for winter, summer, Nili and perennial crops to the total water budget. In addition, crop water productivity and the economics of the land and water units were included in current study. This assessment can help redraw the agricultural map in different climatic regions according to the productive excellence and economic return of the land and water units.

2. Materials and Methods

Study Area:

Egypt has been divided into five geographical regions, taking into consideration the distinctive features of the agricultural regions (SADS, 2009). They are:

Upper Egypt:

Including Asyut, Sohag, Qena, Aswan and the New Valley governorates;

Middle Egypt:

Including Giza, Bani-Sweif, Al-Fayoum, and Minya governorates;

Middle Delta:

Including Al-Qaliobeya, Al-Menoufeya, Al-Gharbeya, Al-Dakahleya, Kafr El-Sheikh and Dumyat governorates;

Eastern Delta:

Including Al-Sharkeya, Port Said, Ismailia, Suez, Northern Sinai and Southern Sinai governorates;

Western Delta:

Including Al-Beherah, Alexandria, Al-Nubareyah, and Matrouh governorates.

In this study, due to the lack of climate data for agricultural climatic regions, three governorates within these regions were selected to calculate the water budget in the old and newly reclaimed lands within the Nile Valley and Delta. These governorates are: Kafr El-Sheikh, representing Eastern, Middle and Western Nile Delta (Lower Egypt); Giza and Asyut to represent Middle and Upper Egypt, respectively. Average climatic values of these governorates were used to calculate the water budget in the lands outside the Nile Valley and Delta.

Meteorological data:

Meteorological data were obtained from the weather station at Agricultural Research Center, Sakha station, Kafr El-Sheikh Governorate, and from Egyptian Meteorological Authority (EMA). Average monthly minimum and maximum temperatures, relative humidity, wind speed and sunshine percent, in addition to total monthly rainfall through the study period (2016-2017) are presented in Table 1.

Cultivated area:

Data of cultivated areas during the 2016/17 winter season and 2017 summer, Nili and perennials for the selected areas of this study were obtained from the Agricultural Economic Research Institute Bulletins (AERI, Volumes 2016-2017).

Table (1): Average monthly weather data for Kafr El-Sheikh, Giza and Asyut in 2016and 2017.

Month	Kafr El-Sheikh, 2016						Giza, 2016						Asyut, 2016					
	Min. °C	Max. °C	RH %	WS m/s	SS %	RF mm	Min. °C	Max. °C	RH %	WS m/s	SS %	RF mm	Min. °C	Max. °C	RH %	WS m/s	SS %	RF mm
January	6.3	18.4	75	0.8	69	42.7	7.9	19.4	60	1.7	68	9.5	5.2	19.0	62	3.2	85	0.0
February	9.4	22.6	69	0.7	71	0.0	10.4	24.4	54	1.6	72	0.5	9.3	24.6	52	3.0	88	0.0
March	11.6	24.5	70	0.7	73	13.2	13.1	27.3	44	2.1	73	0.0	13.4	28.1	42	3.6	83	0.0
April	18.6	30.0	62	1.0	78	0.0	16.7	33.5	38	1.9	75	0.0	17.5	34.9	34	3.6	81	0.0
May	22.8	30.4	59	1.1	78	0.0	19.0	34.6	39	2.1	80	0.0	20.1	36.2	29	4.1	85	0.0
June	26.3	33.6	62	1.3	85	0.0	22.5	38.6	32	2.0	86	0.0	24.6	40.7	30	4.1	90	0.0
July	26.1	33.7	70	1.2	84	0.0	24.0	37.2	46	2.1	85	0.0	24.2	37.3	39	4.1	90	0.0
August	26.0	33.6	70	1.1	86	0.0	24.5	36.5	45	2.1	85	0.0	24.0	37.3	39	4.1	92	0.0
September	24.3	32.6	68	1.1	85	0.0	22.3	35.4	44	1.9	85	0.0	21.6	35.0	45	4.6	89	0.0
October	21.7	29.8	69	1.1	83	0.0	19.8	32.4	53	2.0	82	0.0	17.7	32.7	52	4.1	88	1.0
November	17.9	24.9	68	0.7	77	0.0	14.8	27.4	55	1.8	78	0.0	12.8	26.9	57	3.2	87	0.0
December	10.8	19.3	75	0.8	66	25.8	8.7	20.9	58	1.7	70	1.0	6.4	19.7	62	3.5	87	0.0
Average	18.5	27.8	68	1.0	78	81.7	17.0	30.6	47	1.9	78	11.0	16.4	31.0	45	3.8	87	1.0
	Kafr El-Sheikh, 2017						Giza, 2017						Asyut, 2017					
Month	Min. °C	Max. °C	RH %	WS m/s	SS %	RF mm	Min. °C	Max. °C	RH %	WS m/s	SS %	RF mm	Min. °C	Max. °C	RH %	WS m/s	SS %	RF mm
January	5.7	18.2	75	0.6	69	9.6	6.9	19.4	60	1.7	68	0.0	5.4	19.2	57	3.1	85	0.0
February	10.2	19.7	73	0.7	71	25.2	8.0	21.5	60	1.7	72	0.8	6.6	20.9	53	3.2	88	0.0
March	17.9	21.7	73	1.0	73	0.0	12.0	24.4	48	1.7	73	0.0	11.0	25.2	44	3.6	83	0.0
April	21.6	26.5	65	1.0	78	10.6	15.0	29.2	41	2.0	75	1.6	15.4	31.3	38	3.5	81	0.0
May	25.8	30.6	62	1.2	78	0.0	19.4	34.6	35	2.0	80	0.0	20.1	36.3	33	3.3	85	0.0
June	28.1	32.5	66	1.2	85	0.0	22.3	36.7	36	2.1	86	0.0	23.5	37.4	36	4.3	90	0.0
July	29.0	34.2	71	0.9	84	0.0	24.5	38.2	42	2.0	85	0.0	25.4	39.3	33	3.4	90	0.0
August	28.3	33.9	71	0.8	86	0.0	24.6	37.1	46	2.0	85	0.0	24.6	37.9	41	3.7	92	0.0
September	25.9	32.5	68	1.0	85	0.0	22.2	34.9	46	1.9	85	0.0	20.9	35.2	47	4.4	89	0.0
October	24.0	28.7	68	0.9	83	0.0	18.5	31.0	47	1.9	82	0.0	16.7	30.3	48	3.6	88	0.0
November	19.9	23.7	72	0.6	77	9.3	13.7	25.5	54	1.7	78	0.0	10.9	25.0	56	3.1	87	0.0
December	8.4	21.5	77	0.5	66	5.6	12.4	23.9	64	1.5	70	0.0	9.0	23.1	60	3.0	87	0.0
Average	20.4	27.0	70	0.9	78	60.3	16.6	29.7	48	1.9	78	2.4	15.8	30.1	46	3.5	87	0.0

where: Min. and Max. = minimum and maximum temperatures °C; RH =relative humidity (%); WS= wind speed (m/sec); SS = sunshine (%) and RF = rainfall (mm).

Water budget for Egyptian crops:

Crop water requirement is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field. It refers to the amount of water that needs to be applied considering the efficiencies of the irrigation system, while crop evapotranspiration refers to the amount of water that is lost to the atmosphere through plant leaves (transpiration) and soil surface (evaporation). The irrigation water requirement also includes additional water for leaching of salts and to compensate for non-uniformity of water application (Allen et al., 1998).

To calculate water budget for agricultural crops, four steps are followed:

1. **Calculate reference crop evapotranspiration (ETo):**

The ETo was calculated by FAO Penman-Monteith method, using the decision support software CROPWAT 8.0 developed by FAO, based on Allen et al. (1998). The equation used for calculating ETo is described as follows:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where ET_o is the reference crop evapotranspiration (mm day^{-1}), R_n is the net radiation at the crop surface (MJ m^{-2} day^{-1}), G is the soil heat flux density (MJ m^{-2} day^{-1}), T is the mean daily air temperature at 2 m height (°C), u_2 is the wind speed at 2 m height (m s^{-1}), e_s is the saturation vapor pressure (kPa), $e_a$is the actual vapor pressure (kPa), e_s - e_a is the vapor pressure deficit (kPa), Δ is the slope of the pressure-temperature curve (kPa °C^{-1}), and γ is the psychrometric constant (kPa °C^{-1}).

2. **Calculate crop water use (crop evapotranspiration, ETc)**

According to Allen et al. (1998), crop evapotranspiration (ETc) is calculated by multiplying the reference crop evapotranspiration (ET_o), by crop coefficient(K_c):

$ET_c = K_c ET_o$

Where ET_c is the crop evapotranspiration (mm day^{-1}), K_c is the crop coefficient (dimensionless), and ET_o is the reference crop evapotranspiration (mm day^{-1}).

The Kc values of the crops used in this study were obtained from FAO No. 56 and some values were adjusted according to the results of actual experiments in Egypt.

3. **Calculate irrigation water requirement (IWR):**

IWR = ETc/ IE

Where IE is the irrigation efficiency.

Irrigation efficiency can be defined in terms of: 1) the irrigation system performance, 2) the uniformity of the water application, and 3) the response of the crop to irrigation (Howell, 2003). In this study, the application efficiency that is related to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field was used. The irrigation efficiency values used in this study were:

- 60% for surface irrigation system (Jensen, 1980).
- 50% for submerged crops, i.e. rice (Dastane, 1972; and Doorenbos and Pruitt, 1977).
- 80% for the modern irrigation systems.

4. **Water budget (WB):**

The total water budget for the selected areas and crops was calculated according to the following equation:

$$WB = \sum_{i=1}^{i=n} (IWR)i \text{ X } (Area)i$$

where: (IWR)i: is the irrigation water requirement of crop i

(Area)i: is the cultivated area of crop i

Selected crops:

The water budget was calculated for the following crops:

Winter season:

Barley, chick peas, faba bean (green), faba bean (dry), fenugreek (green), fenugreek (dry), flax, garlic, lentil, lupine, onion, sugar beet, wheat, beans (green), beans (dry), cabbage, carrot, cucumber, eggplant, lettuce, peas (green), peas (dry), pepper, potato, squash, strawberry and tomato.

Summer season:

Cotton, ground nut, maize, onion, rice, soybean, sunflower, beans (green), beans (dry), cabbage, cantaloupe, cucumber, eggplant, jews mallow, okra, pepper, potato, squash, sweet melon, taro, tomato and water melon.

Nili season:

Beans (green), beans (dry), cabbage, cucumber, eggplant, maize, pepper, potato, squash, sunflower and tomato.

Perennial crops: apple, banana, date, grapes, mango, olive, orange, peach and sugar cane.

Crop water productivity (CWP):

According to Wichelns (2014), water productivity is, most often, defined as the average amount of output per unit of water applied on a field (Equation 1) or per unit of water evapo-transpired (Equation 2).

$$WP(AW) = \frac{Output \left(\frac{kg}{ha}\right)}{Appliedwater \left(\frac{m^3}{ha}\right)} \ldots\ldots\ldots\ldots. (equation\ 1)$$

$$WP\ (ET) = \frac{Output\left(\frac{kg}{ha}\right)}{Evapo - transpiredwater\left(\frac{mm}{ha}\right)} \ldots\ldots (equation\ 2)$$

the outputs refer to the actual yield of the crops under study, which were obtained from AERI(Volumes 2016-2017).

Economics of the land and water units

Data of the economic return per unit of land (farm net return) was obtained from AERI(Volumes 2016-2017). The productivity of the main and secondary crop products, average prices, the value of ~~the~~ main and secondary crop products, total revenue, cost of all agricultural operations, rent of the land unit, total cost and farm net return were calculated. Regarding the economics of water unit, the following equations were used for the amounts of water consumed (ETC) and applied (IWR):

Economic return of water $\text{unit}_{ETc} = \frac{\textbf{farmnetreturn}}{\textbf{cropevapotranspiration, ETc}}$(LE/ m^3)

Economic return of water $\text{unit}_{IWR} = \frac{\textbf{farmnetreturn}}{\textbf{irrigationwaterrequirements, IWR}}$(LE/ m^3)

3. Results and Discussion

Cultivated and cropped areas and cropping intensity:

Egyptian crops are grown in two to three seasons, winter (October through April), summer (May through September), and sometimes in the Nili season (June through October), in addition to the perennial crops that grow all over the year. The cultivated land of Egypt inside and outside the Nile Valley and Delta totals about 3.8 million hectares in 2016/ 2017 (Table 2). The largest cultivated area in Egypt is in Lower Egypt with a cultivated area of 1.9 million hectares and represents approximately 50% of the total cultivated area. While, the cultivated area in Middle and Upper Egypt registered about 0.6 and 0.5 million hectares, respectively, which represent about 16 and14% of the total cultivated area. Total newly cultivated area outside the Nile Valley and Delta amounted to 0.8 million hectares and represents 20% of the total cultivated area in Egypt. As a result of cultivating the land more than one time a year with a cropping intensity of 1.76, the cropped area inside the Nile Valley and Delta is estimated at 5.7 million hectares and 1.0 million hectares of the newly reclaimed lands outside the Nile Valley and Delta (Table 3).

Table 2: Cultivated areas (ha)inside and outside the Nile Valley and Delta in 2016/2017.

Cultivated area	Inside the Nile Valley and Delta				Outside the Nile Valley and Delta (New Lands)	Grand Total
	Lower Egypt	Middle Egypt	Upper Egypt	Total		
Hectare	1,906,172	595,939	542,433	3,044,544	760,985	3,805,528
%	50.1	15.7	14.3	80	20	100

Table 3: Total cropped area inside and outside the Nile Valley and Delta in 2016/2017 (ha).

Cropped area	Inside the Nile Valley and Delta				Outside the Nile Valley and Delta (New Lands)	Grand Total
	Lower Egypt	Middle Egypt	Upper Egypt	Total		
Hectare	3,619,753	1,112,776	925,374	5,657,903	1,024,681	6,682,584

Source of data: Agricultural Economic Research Institute Bulletins (AERI, Volumes 2016-2017).

Reference evapotranspiration for the studied areas (ETo):

The calculated monthly ETo values for Lower, Middle and Upper Egypt in 2016 and 2017 are presented in Figs. 1 and 2. It is clear from the results that Lower Egypt recorded the lowest ETo values as compared with Middle and Upper Egypt. Results showed that there are inter annual differences (between months) in ETo values through the study period. The highest ETo values were recorded for June followed by July, while January followed by December registered the lowest ones. The obtained results agreed with what was mentioned in FAO report (http://www.fao.org/docrep/X0490E/x0490e07.htm), indicating that the evapotranspiration demand is high under hot-dry weather due to the dryness of the air and the amount of energy available as direct solar radiation and latent heat. Under these circumstances, much water vapor can be stored in the air, while wind may promote the transport of water allowing more water vapor to be taken up. On the other hand, under humid weather conditions, the high humidity of the air and the presence of clouds cause the evapotranspiration rate to be lower.

Fig. 1: Monthly reference evapotranspiration (ETo) for Lower, Middle and Upper Egypt in 2016

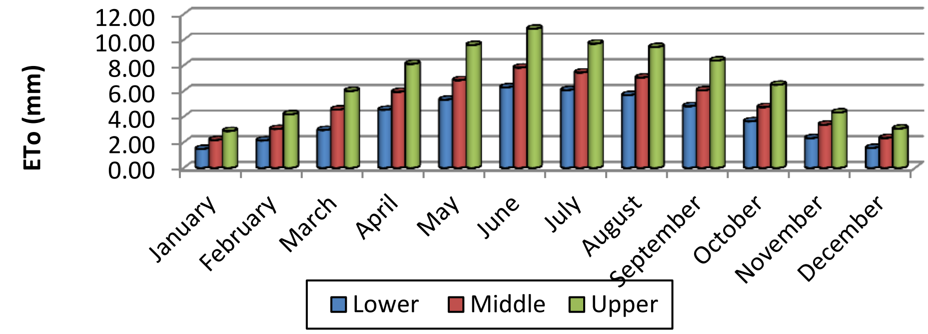
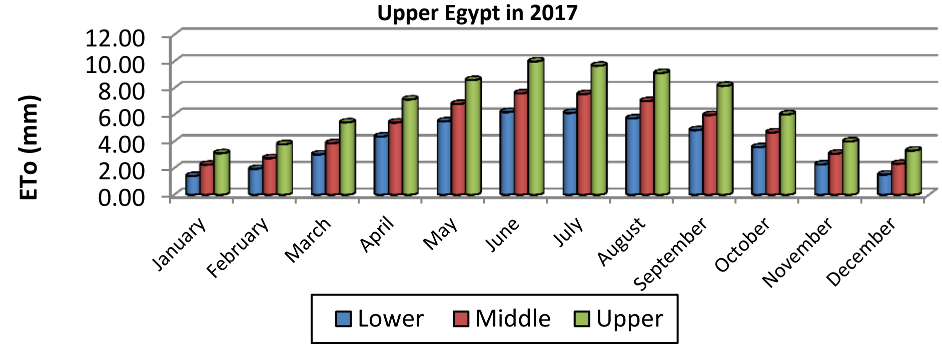


Fig. 2: Monthly reference evapotranspiration (ETo) for Lower, Middle and Upper Egypt in 2017



Water consumption (crop evapotranspiration, ETc):

The calculated ETc values for winter, summer, Nili and perennial crops under different agro-climatic areas are presented in Figs. 3 to 6. Results indicated, in general, that Upper Egypt registered higher crop water consumption as compared with Lower and Middle Egypt. Results indicated for winter season that, strawberry, sugar beet, onion and wheat consumed the highest amounts of water as compared with the other crops because their season length is longer than the other winter crops. In the same direction, taro (colocasus) and cotton in summer season; eggplant, pepper, cabbage, and tomato in Nili season. As for the perennials, bananas, sugarcane and mango were the highest water consuming crops. Average ETc values varied from 2149 to 5114 m^3/ ha for winter crops; 4218 to 11022 m^3/ ha for summer crops; 4544 to 8124 m^3/ha for Nili crops; and 9641 to 19508 m^3/ ha for perennials.

Fig. 3: Water consumption (crop evapotranspiration, ETc) for winter crops under different climatic areas conditions during 2016/2017

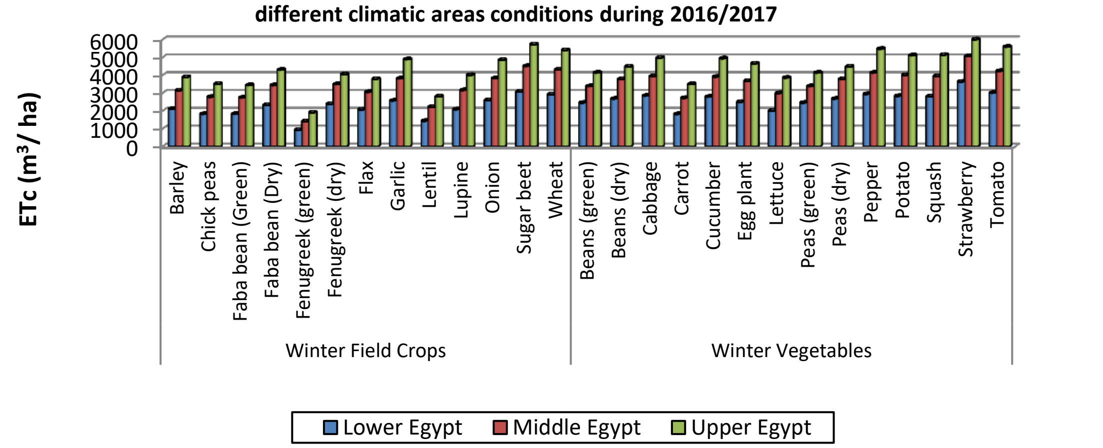


Fig. 4: Water consumption (crop evapotranspiration, ETc) for summer crops under different climatic areas conditions during 2017

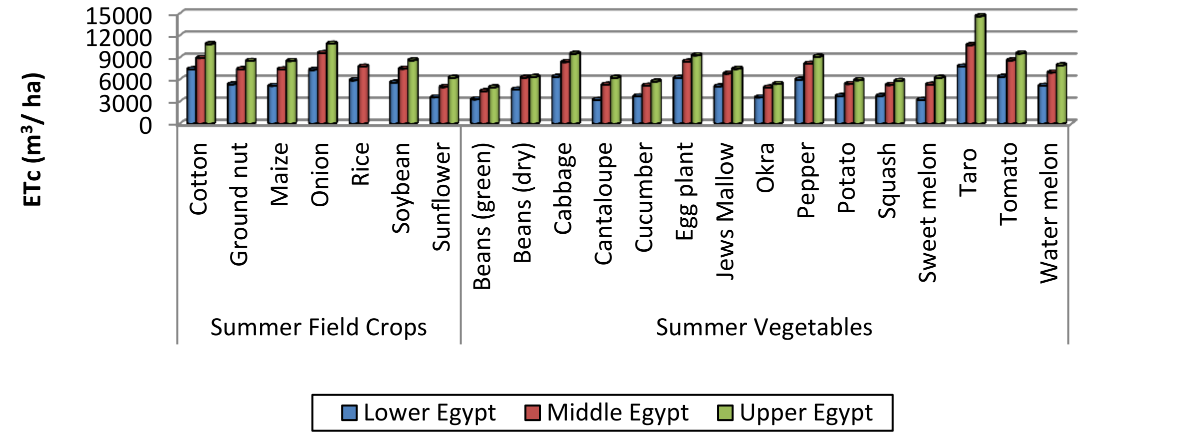


Fig. 5: Water consumption (crop evapotranspiration, ETc) for Nili crops under different climatic areas conditions during 2017

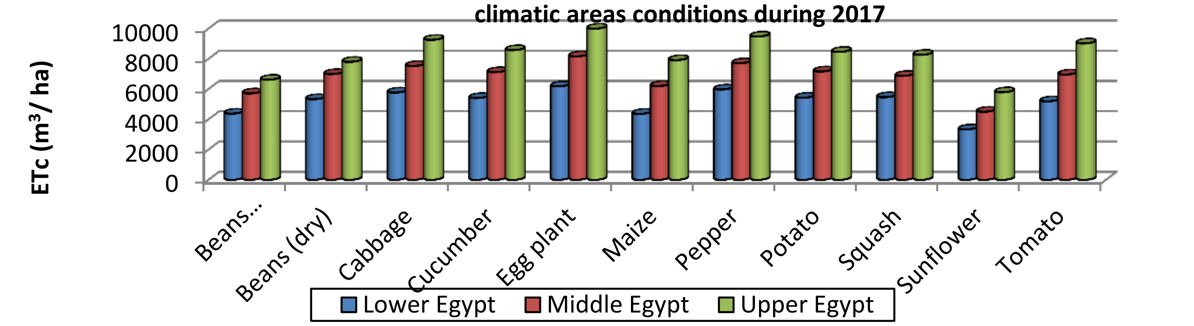
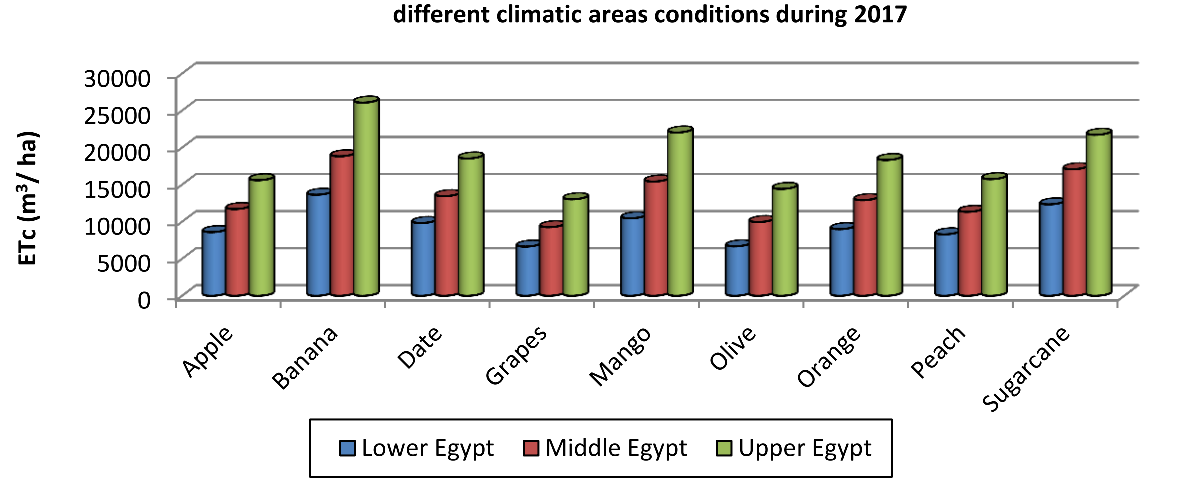


Fig. 6: Water consumption (crop evapotranspiration, ETc) for perennial crops under different climatic areas conditions during 2017



Water Budget (WB):

Winter crops:

Results presented in Table 4 indicated that, the WB for winter crops in the old and new lands within the Nile Valley and Delta reached about 11.9 and 1.5 billion m^3, respectively. Whereas, the WB value outside the Nile Valley and Delta (the New lands) was around 2.0 billion m^3. Accordingly, the total WB for winter crops reached about 15.4 billion m^3.

Summer crops:

The calculated WB values for summer crops in the old and new lands inside the Nile Valley and Delta recorded 23.8 and 1.9 billion m^3, respectively. However, the value outside the Nile Valley and Delta

(New lands) amounted to 2.0 billion m^3 (Table 5). The total WB for summer crops was 27.7 billion m^3.

Nili crops:

Results of WB for Nili crops (Table 6) showed that values for the respective old and new lands inside the Nile Valley and Delta were 1.9 and 0.07 billion m^3. Whereas, the value outside the Nile Valley and Delta (New lands) was 0.3 billion m^3. Consequently, the total WB for Nili crops recorded about 2.2 billion m^3.

Perennial crops:

Results tabulated in Table 7 indicated that, WB values for perennial crops in the old and new lands inside the Nile Valley and Delta were 8.8 and 3.0 billion m^3, respectively. However, the water budget outside the Nile Valley and Delta (New lands) recorded 5.6 billion m^3. Consequently, the total WB for the perennials recorded 17.4 billion m^3.

Total cropped area and WB for the Egyptian crops in the selected locations:

Results presented in Table 8 show the total cropped area and WB for the selected agricultural crops. Total cropped area for winter, summer, Nili and perennial crops were 2.9, 2.7, 0.2 and 0.9 million hectares, respectively. According to the total cropped area, the total WB amounted to 15.4, 27.7, 2.2 and 17.4 billion m^3 for the respective growing seasons.

Table 4: Water budget (WB, m^3) for winter crops inside and outside the Nile Valley and Delta in Egypt according to the cropped area in 2016/ 2017.

Crop	WB inside the Nile Valley and Delta		WB outside the Nile Valley and Delta	Grand Total	% from the total WB for all agricultural crops
	Old lands	New lands	New lands		
Winter field crops					
Barley	17,341,140	22,392,666	51,190,551	90,924,356	0.15
Chick peas	9,250,335	511,146		9,761,481	0.02
Faba bean (Green)	5,249,285	916,191		6,165,476	0.01
Faba bean (Dry)	129,968,657	21,694,099	57,554,190	209,216,946	0.33
Fenugreek (dry)	6,646,628	829,605	447,146	7,923,379	0.01
Flax	20,239,375	330,505		20,569,880	0.03
Garlic	60,268,042	4,098,414	10,073,233	74,439,689	0.12
Lentil	2,679,540			2,679,540	0.004
Lupine	450,592			450,592	0.001
Onion	274,330,260	63,007,440	26,774,290	364,111,990	0.58
Sugar beet	901,464,285	212,736,266	42,199,507	1,156,400,057	1.84
Wheat	6,153,779,210	568,483,527	613,032,708	7,335,295,446	**11.70**
Winter vegetables					
Beans (green)	14,436,069	1,627,178	35,749,052	51,812,298	0.08
Beans (dry)	61,636,781	139,219	9,481	61,785,481	0.10
Cabbage	54,897,003	5,453,442	169,199	60,519,644	0.10
Carrot	23,363,472	480,634	876,778	24,720,883	0.04
Cucumber	14,358,322	3,305,924	6,862,569	24,526,816	0.04
Eggplant	53,313,508	23,275,665	5,825,690	82,414,862	0.13
Lettuce	13,312,306	80,993	19,963	13,413,262	0.02
Peas (green)	61,838,963	3,283,094	15,553,518	80,675,575	0.13
Peas (dry)	510,469	-	187,722	698,191	0.001
Pepper	38,968,599	17,949,634	12,765,399	69,683,631	0.11
Potato	318,980,735	11,042,856	148,943,170	478,966,761	0.76
Squash	28,812,900	12,083,563	11,554,474	52,450,937	0.08
Strawberry	26,460,020	92,666	23,198,296	49,750,983	0.08
Tomato	169,642,830	126,392,152	91,320,675	387,355,657	0.62
Other winter crops	3,474,857,845	419,259,600	836,589,177	4,730,706,622	7.54
Total winter crops	11,937,057,169	1,519,466,477	1,990,896,788	15,447,420,435	24.6

Note: In this table and other tables, the absence of some values reflects the absence of crop cultivation under the conditions of this type of land.

Table 5: Water budget (WB, m^3) for summer crops inside and outside the Valley and Nile Delta in Egypt according to cropped area in 2017.

Crop	WB inside the Nile Valley and Delta		WB outside the Nile Valley and Delta	Grand Total	% from the total WB for all agricultural crops
	Old lands	New lands	New lands		
Summer field crops					
Cotton	1,015,425,083	93,781,011	2,933,292	1,112,139,386	1.77
Ground nut	156,147,799	59,735,713	363,750,393	579,633,905	0.92
Maize	9,009,573,404	455,617,908	576,610,008	10,041,801,320	**16.01**
Onion	12,894,150	1,360,444	4,249,601	18,504,195	0.03
Rice	5,933,814,088	475,210,667	10,108,671	6,419,133,426	**10.24**
Soybean	152,751,289	884,969	2,703,740	156,339,997	0.25
Sunflower	26,177,802	1,872,804	17,466,573	45,517,179	0.07
Summer vegetables					
Beans (green)	11,017,922	1,235,551	155,966	12,409,438	0.02
Beans (dry)	207,319,688	10,423,922	16,635,863	234,379,472	0.37
Cabbage	32,903,097	793,555	3,150,301	36,846,952	0.06
Cantaloupe	19,555,308	7,017,751	46,245,924	72,818,984	0.12
Cucumber	58,436,534	9,940,903	16,943,670	85,321,107	0.14
Eggplant	165,820,006	49,177,194	22,830,962	237,828,161	0.38
Jews Mallow	42,007,685	2,616,685	647,187	45,271,557	0.07
Okra	25,084,314	4,076,289	650,063	29,810,665	0.05
Pepper	124,537,471	66,626,441	22,450,500	213,614,411	0.34
Potato	319,608,358	14,763,219	25,984,050	360,355,626	0.57
Squash	36,245,856	12,284,947	20,014,126	68,544,929	0.11
Sweet melon	12,259,030	6,543,188	463,278	19,265,496	0.03
Taro	37,308,406	940,922		38,249,328	0.06
Tomato	386,511,065	201,736,949	267,249,610	855,497,624	1.36
Watermelon	76,846,153	18,653,320	142,447,697	237,947,169	0.38
Other summer crops	5,898,759,673	395,533,778	448,665,196	6,742,958,646	10.75
Total summer crops	23,761,004,179	1,890,828,126	2,012,356,669	27,664,188,973	44.1

Table 6: Water budget (WB, m^3) for Nili crops inside and outside the Valley and Nile Delta in Egypt according to cropped area in 2017.

Crop	WB inside the Nile Valley and Delta		WB outside the Nile Valley and Delta	Grand Total	% from the total WB for all agricultural crops
	Old lands	New lands	New lands		
Beans (green)	22,552,708	592,647	4,668,893	27,814,248	0.04
Beans (dry)	53,957,597			53,957,597	0.09
Cabbage	14,496,081	2,030,923	50,910	16,577,914	0.03
Cucumber	6,516,526	873,651	366,458	7,756,636	0.01
Eggplant	17,410,983	9,970,656	36,367,594	63,749,233	0.10
Maize	1,280,691,653	10,760,209	86,961,444	1,378,413,307	2.20
Pepper	10,896,001	6,103,529	14,992,256	31,991,785	0.05
Potato	243,838,136			243,838,136	0.39
Squash	10,526,352	3,211,261	17,889	13,755,502	0.02
Sunflower	253,406		539,640	793,046	0.001
Tomato	47,207,861	18,735,510	47,893,165	113,836,536	0.18
Other Nili crops	199,954,937	18,602,328	61,280,101	279,837,366	0.45
Total Nili crops	1,908,302,242	70,880,714	253,138,349	2,232,321,306	3.56

Table 7: Water budget (WB, m^3) for perennial crops in the old and new lands in Egypt according to cropped area in 2017.

Crop	WB inside the Nile Valley and Delta		WB outside the Nile Valley and Delta	Grand Total	% from the total WB for all agricultural crops
	Old lands	New lands	New lands		
Apple	22,880,262	10,842,341	390,560,796	424,283,399	0.68
Banana	563,358,209	79,405,827	204,522,522	847,286,557	1.35
Date	337,077,583	302,826,041	320,482,660	960,386,283	1.53
Grapes	337,518,968	100,058,682	513,732,046	951,309,696	1.52
Mango	1,025,814,522	548,905,143	420,383,467	1,995,103,132	3.18
Olive	74,718,833	321,896,871	674,618,833	1,071,234,538	1.71
Orange	1,049,737,302	393,550,144	479,250,535	1,922,537,982	3.07
Peach	7,059,653	19,811,442	347,656,246	374,527,341	0.60
Sugarcane	4,092,886,440	514,730,164	798,938	4,608,415,541	**7.35**
Other perennials	1,266,719,465	700,097,557	2,236,983,603	4,203,800,625	6.70
Total perennials	8,777,771,237	2,992,124,210	5,588,989,647	17,358,885,094	27.68

Table 8: Irrigation water budget for Egyptian crops according to cropped area in 2016/2017

Groups	Cropped area (ha)	Water budget (m^3)
Winter crops	**2,887,853**	**15,447,420,435**
Summer crops	**2,665,702**	**27,664,188,973**
Nili crops	**211,353**	**2,232,321,306**
Perennials	**917,676**	**17,358,885,094**
Grand Total	**6,682,584**	**62,702,815,807**

Crops that consumed the largest proportion of the total water budget:

Results of this study indicated that, maize, wheat, rice and sugarcane nearly consumed half of the water budget (47.5%) allocated to agricultural crops and occupied 44.7% of the total cropped area (Table 9). The agricultural area of these four respected crops were about 1.09, 1.22, 0.54 and 0.14 million ha. The total water budget for each crop, respectively, were about 11.4, 7.3, 6.4 and 4.6 billion m^3.

Table 9: Crops that consumed the largest proportion of the total water budget.

crop	Area (ha)	% of grand total cropped area	Total WB (m^3)	% of total water budget
Maize (summer and Nili seasons)	1,087,541	16.3	11,420,214,627	18.2
Wheat	1,217,381	18.2	7,335,295,446	11.7
Rice	544,623	8.1	6,419,133,426	10.2
Sugarcane	135,932	2.0	4,608,415,541	7.3
Total (four crops)	2,985,477	44.7	29,783,059,040	47.5
Grand total of cropped area and water budget	6,682,584		62,702,815,807	

Crop water productivity (CWP, kg/m^3 water consumed):

Results presented in Tables (10 - 13) indicated that, crops with the highest CWP values were sugar beet, onion, and garlic for winter field crops; carrot, tomato, lettuce, eggplant, strawberry, potato, and cabbage for winter vegetables; onion for summer field crop; potato, cantaloupe, watermelon, tomato, and cucumber for summer vegetables. Eggplants recorded the highest CWP for Nili crops and sugarcane for perennials. The results indicated that, some crops were superior in CWP under new lands conditions as compared with old lands. These crops are: barley, faba bean (dry), beans (dry), lettuce, potato, strawberry, maize, sunflower, apple, banana, mango and orange.

Generally, CWP values varied from 0.52 to 10.61 kg/m^3 for winter field crops; 0.66 to 11.84 kg/m^3 for winter vegetables; 0.29 to 2.64 kg/m^3 for summer field crops; 0.55 to 5.82 kg/m^3 for summer vegetables; 0.34 to 5.05 kg/m^3 for Nili crops; and 0.66 to 4.77 kg/m^3 for perennials.

Table 10: Crop water productivity (CWP, kg/ m^3 water consumed) for winter crops inside and outside the Nile Valley and Delta in 2016/ 2017.

Crop	CWP inside the Nile Valley and Delta		CWP outside the Nile Valley and Delta	Average CWP
	Old lands	New lands	New lands	
Winter Field crops				
Barley	1.11	1.07	1.51	1.23
Chick peas	0.83	0.53		0.68
Faba bean (Green)	5.02	3.36		4.19
Faba bean (Dry)	0.96	0.85	1.15	0.99
Fenugreek (dry)	0.66	0.44	0.44	0.52
Flax	3.96	4.09		4.02
Garlic	6.06	4.56	5.54	5.39
Lentil	1.05			1.05
Lupine	0.69			0.69
Onion	9.73	10.04	9.26	9.68
Sugar beet	11.33	10.79	9.71	10.61
Wheat	1.66	1.48	1.49	1.55
Winter vegetables				
Beans (green)	3.83	2.73	2.40	2.98
Beans (dry)	0.56	0.52	1.05	0.71
Cabbage	7.54	8.22	6.17	7.31
Carrot	11.67	15.28	8.56	11.84
Cucumber	5.99	5.02	5.15	5.39
Eggplant	9.22	10.37	5.14	8.24
Lettuce	7.05	7.89	10.50	8.48
Peas (green)	3.17	2.67	2.65	2.83
Peas (dry)	0.99		0.33	0.66
Pepper	4.16	4.22	4.10	4.16
Potato	6.33	8.56	7.69	7.53
Squash	5.90	4.10	4.04	4.68
Strawberry	7.55	7.80	7.92	7.76
Tomato	10.98	11.11	7.59	9.89

Table 11: Crop water productivity (CWP, kg/ m^3 water consumed) for summer crops inside and outside the Nile Valley and Delta in 2017.

Crop	CWP inside the Nile Valley and Delta		CWP outside the Nile Valley and Delta	Average CWP
	Old lands	New lands	New lands	
Summer field crops				
Cotton	0.32	0.28	0.27	0.29
Ground nut	0.54	0.48	0.52	0.52
Maize	1.14	0.93	1.22	1.09
Onion	3.49	2.44	1.98	2.64
Rice	1.34	1.12	1.18	1.22
Soybean	0.39	0.34	0.31	0.35
Sunflower	0.49	0.58	0.71	0.59
Summer vegetables				
Beans (green)	2.69	2.64	1.26	2.20
Beans (dry)	0.48	0.50	0.67	0.55
Cabbage	3.91	2.92	2.52	3.12
Cantaloupe	4.90	6.30	5.57	5.59
Cucumber	4.43	3.35	5.27	4.35
Eggplant	3.58	2.57	3.43	3.19
Jews Mallow	2.69	1.17	1.29	1.72
Okra	2.69	2.34	2.25	2.43
Pepper	2.58	1.71	2.89	2.39
Potato	6.07	5.20	6.21	5.82
Squash	4.23	3.10	4.08	3.80
Sweet melon	4.53	3.59	3.28	3.80
Taro	3.29	2.96		3.13
Tomato	4.98	5.21	4.04	4.74
Watermelon	5.93	4.43	4.71	5.02

Table 12: Crop water productivity (CWP, kg/ m^3 water consumed) for Nili crops inside and outside the Nile Valley and Delta in 2017.

Crop	CWP inside the Nile Valley and Delta		CWP outside the Nile Valley and Delta	Average CWP
	Old lands	New lands	New lands	
Beans (green)	2.38	2.30	1.19	1.96
Beans (dry)	0.34			0.34
Cabbage	3.72	3.59	2.07	3.13
Cucumber	2.35	2.35	1.56	2.09
Eggplant	3.16	3.07	2.88	3.04
Maize	1.08	0.72	1.29	1.03
Pepper	1.95	2.15	2.22	2.11
Potato	3.44			3.44
Squash	2.31	2.86	1.18	2.11
Sunflower	0.52		0.73	0.63
Tomato	5.71	5.78	3.66	5.05

Table 13: Crop water productivity (CWP, kg/ m^3 water consumed) for perennial crops inside and outside the Nile Valley and Delta in 2017.

Crop	CWP inside the Nile Valley and Delta		CWP outside the Nile Valley and Delta	Average CWP
	Old lands	New lands	New lands	
Apple	1.44	1.12	2.15	1.57
Banana	2.19	2.51	2.46	2.39
Date	4.73	0.96	0.94	2.21
Grapes	2.24	2.29	2.34	2.29
Mango	0.53	0.49	0.98	0.66
Olive	1.06	1.38	1.01	1.15
Orange	1.89	1.56	1.97	1.81
Peach	1.63	1.39	1.37	1.46
Sugarcane	6.62	6.37	1.31	4.77

Economic evaluation of land and water units:

Results of the economic evaluation of the land unit (farm net return, LE/ha), water consumption unit (LE/ m^3_{ETc}), and irrigation water requirements unit (LE/ m^3_{IWR}) for the studied area are presented in Tables (14 - 17). The results could be summarized in the following points:

I. Farm net return:

The superiority in the farm net return was found for onion, faba bean (green), garlic, chick peas of the winter field crops; strawberry, peas (dry), carrot, tomato, beans (dry), lettuce, eggplant, cucumber, squash, peas (green), potato of the winter vegetables; groundnut, cotton of the summer field crops; beans (dry), jews mallow, tomato, okra, watermelon, sweet melon, eggplant, beans (green) of summer vegetables; beans (dry), tomato, eggplant, beans (green) of Nili crops; and all perennial crops. Each of the previous crops earned a net farm return of more than 20,000 LE/ha.

Values of farm net return ranged between 126 and 48621 LE/ha for winter field crops; 14386 and 157810 LE/ha for winter vegetables; 1190 and 37298 LE/ha for summer field crops; 8750 and 83095 LE/ha for summer vegetables; 2793 and 66476 LE/ha for Nili crops; and 46136 and 131219 LE/ha for perennials.

II. Economics of the water consumption unit (LE/ m^3_{ETc})

Values of the economics of water consumption unit ranged from 0.04 to 16.05 LE/m^3_{ETc} for winter field crops; 3.68 to 30.86 LE/$m^3_{ETc}$for winter vegetables; 0.16 to 4.03 LE/$m^3_{ETc}$for summer field crops; 1.07 to 14.45 LE/$m^3_{ETc}$for summer vegetables; 0.61 to 9.91 LE/$m^3_{ETc}$for Nili crops; and 2.71 to 8.41 LE/m^3_{ETc} for perennial crops. Results showed that, the crops that achieved an economic return from the water consumption unit exceed 8 LE/m^3_{ETc}were: Faba bean (green), onion, garlic, chick peas for winter field crops; strawberry, peas (dry), carrot, lettuce, beans (dry), tomato, eggplant, cucumber for winter vegetables; beans (dry), okra, sweet melon for summer vegetables; beans (dry) for Nili crops; and date for perennial crops. Regarding summer field crops, the highest economic return from unit of water consumption reached about 4 LE/m^3_{ETc}.

III. Economics of the irrigation water requirements unit in the old lands (LE/ m^3_{IWR})

Economics of the water unit for irrigation water requirements in the old lands varied between 0.02 and 9.63 LE/m^3_{IWR} for winter field crops; 2.21 and 18.51 LE/m^3_{IWR} for winter vegetables; 0.10 and 2.42 LE/m^3_{IWR} for summer field crops; 0.64 and 8.67 LE/m^3_{IWR} for summer vegetables; 0.35 and 5.94 LE/m^3_{IWR} for Nili crops; and 1.62 and 5.05 LE/m^3_{IWR} for perennial crops.

IV. Economics of the irrigation water requirements unit in the new lands (LE/ m^3_{IWR})

Values of the economics of the irrigation water requirements unit in the new lands varied from 0.31 to 12.84 LE/m^3_{IWR} for winter field crops; 2.94to24.69 LE/m^3_{IWR} for winter vegetables; 0.13to3.22 LE/m^3_{IWR} for summer field crops; 1.13to11.56 LE/m^3_{IWR} for summer vegetables; 0.47to3.64 LE/m^3_{IWR} for Nili crops; and 2.17to6.73 LE/$m^3_{IWR}$for perennial crops.

Table 14: Economic return of land and water units for winter crops in 2016/ 2017.

Crop	*Farm net return	Economics of water unit		
			Old lands	New lands
	(LE/ha)	(LE/m^3_{ETc})	(LE/m^3_{IWR})	(LE/m^3_{IWR})
Winter Field crops				
Barley	1,183	0.39	0.23	0.31
Chick peas	29,150	10.80	6.48	8.64
Faba bean (Green)	42,736	16.05	9.63	12.84
Faba bean (Dry)	8,564	2.56	1.53	2.04
Fenugreek (dry)	3,245	0.98	0.59	0.79
Flax	6,898	2.32	1.39	1.86
Garlic	41,114	10.95	6.57	8.76
Lentil	7,555	3.52	2.11	
Lupine	126	0.04	0.02	
Onion	48,621	12.96	7.78	10.37
Sugar beet	11,421	2.58	1.55	2.06
Wheat	9,105	2.16	1.30	1.73
Winter vegetables				
Beans (green)	19,567	5.89	3.54	4.71
Beans (dry)	59,552	16.36	9.81	13.09
Cabbage	14,386	3.68	2.21	2.94
Carrot	62,429	23.33	14.00	18.66
Cucumber	43,333	11.18	6.71	8.95
Eggplant	47,374	13.13	7.88	10.50
Lettuce	52,024	17.65	10.59	14.12
Peas (green)	21,543	6.49	3.89	5.19
Peas (dry)	86,467	23.75	14.25	19.00
Pepper	17,826	4.26	2.56	3.41
Potato	20,636	5.19	3.11	4.15
Squash	24,455	6.18	3.71	4.94
Strawberry	157,810	30.86	18.51	24.69
Tomato	60,717	14.21	8.53	11.37

Currency equivalents (as of September 2019): US $1.00 = 16.55 LE
*Data were obtained from AERI (Volumes 2016-2017).

Table 15: Economic return for land and water units for summer crops in Egypt in 2017.

Crop	Farm net return	Economics of the water unit		
	(LE/ha)	(LE/m^3_{ETc})	Old lands (LE/m^3_{IWR})	New lands (LE/m^3_{IWR})
Summer field crops				
Cotton	21,824	2.41	1.45	1.93
Ground nut	23,855	3.36	2.02	2.69
Maize	4,248	0.61	0.36	0.49
Onion	37,298	4.03	2.42	3.22
Rice	12,431	1.82	0.91	0.91
Soybean	1,190	0.16	0.10	0.13
Sunflower	2,640	0.54	0.32	0.43
Summer vegetables				
Beans (green)	23,926	5.67	3.40	4.54
Beans (dry)	83,095	14.45	8.67	11.56
Cabbage	14,286	1.77	1.06	1.41
Cantaloupe	8,750	1.78	1.07	1.42
Cucumber	17,117	3.52	2.11	2.81
Eggplant	27,810	3.49	2.09	2.79
Jews Mallow	51,238	7.96	4.77	6.37
Okra	49,760	10.76	6.46	8.61
Pepper	10,962	1.42	0.85	1.13
Potato	17,145	3.42	2.05	2.74
Squash	12,650	2.56	1.54	2.05
Sweet melon	40,667	8.28	4.97	6.62
Taro	11,762	1.07	0.64	
Tomato	50,110	6.13	3.68	4.90
Watermelon	43,533	6.52	3.91	5.22

Table 16: Economic return for land and water units for Nili crops in Egypt in 2017

Crop	Farm net return	Economics of the water unit		
	(LE/ha)	(LE/m^3_{ETc})	Old lands (LE/m^3_{IWR})	New lands (LE/m^3_{IWR})
Beans (green)	25,345	4.55	2.73	3.64
Beans (dry)	66,476	9.91	5.94	
Cabbage	13,095	1.74	1.04	1.39
Cucumber	12,852	1.83	1.10	1.46
Eggplant	25,431	3.13	1.88	2.50
Maize	3,621	0.59	0.35	0.47
Pepper	9,329	1.21	0.72	0.97
Potato	18,321	2.61	1.57	
Squash	11,038	1.61	0.96	1.29
Sunflower	2,793	0.61	0.37	0.49
Tomato	31,150	4.41	2.65	3.53

Table 17: Economic return for land and water units for perennial crops in Egypt in 2017

Crop	Farm net return (LE/ha)	Economics of the water unit (LE/m^3_{ETc})	Old lands (LE/m^3_{IWR})	New lands (LE/m^3_{IWR})
Apple	81,802	6.84	4.10	5.47
Banana	131,219	6.73	4.04	5.38
Date	117,176	8.41	5.05	6.73
Grapes	64,821	6.72	4.03	5.38
Mango	65,964	4.13	2.48	3.30
Olive	73,250	7.08	4.25	5.66
Orange	72,855	5.43	3.26	4.35
Peach	81,798	6.94	4.16	5.55
Sugarcane	46,136	2.71	1.62	2.17

Conclusions:

From the obtained results it could be concluded that:

- Total cultivated and cropped areas in Egypt during 2016/17 were about 3.8 and 6.7 million ha, respectively, with cropping intensity of 176%.
- The cropped area for winter, summer, Nili and perennial crops were 43.2, 39.9, 3.2 and 13.7%, respectively, of the total cropped area.
- Total water budget (WB) for crops inside and outside the Nile Valley and Delta amounted to 62.7 billion m^3 which represents 78.4% of the total water resources in Egypt.
- The WB of seasonal crops was 24.6% for winter crops, 44.1% for summer crops, 3.6% for Nili crops and 27.7% for perennial crops of the grand total WB.
- Crop water productivity (CWP)varied from 0.52 to 10.61 kg/m^3 for winter field crops; 0.66 to 11.84 kg/m^3 for winter vegetables; 0.29 to 2.64 kg/m^3 for summer field crops; 0.55 to 5.82 kg/m^3 for summer vegetables; 0.34 to 5.05 kg/m^3 for Nili crops; and 0.66 to 4.77 kg/m^3 for perennials.
- Values of farm net return ranged between 126 and 48621 LE/ha for winter field crops; 14386 and 157810 LE/ha for winter vegetables; 1190 and 37298 LE/ha for summer field crops; 8750 and 83095 LE/ha for summer vegetables; 2793 and 66476 LE/ha for Nili crops; and 46136 and 131219 LE/ha for perennials.

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